UNIVERSITY OF WARSAW

Course syllabus

Course title	Cognitive processes modelling I
Instructor(s)	prof. Joanna Rączaszek-Leonardi, dr Julian Zubek, mgr inż. Michał Denkiewicz, mgr Szymon Talaga, mgr Wiktor Rorot
Contact details	E-mails with questions should preferably be sent to all the following instructors: raczasze@psych.uw.edu.pl; j.zubek@uw.edu.pl; michal.denkiewicz@psych.uw.edu.pl Office hours: Joanna Rączaszek-Leonardi: Tuesday 12-14 J. Zubek, M. Denkiewicz: appointments set by e-mail.
Affiliation	Faculty of Psychology, University of Warsaw (JRL, JZ, WR); Faculty of Mathematics and Information Science, Warsaw University of Technology (MD); Robert Zajonc Institute for Social Studies (ST)
Course format	lecture
Number of hours	30 hours
Number of ECTS credits	**3 ECTS credits** 1 ECTS stands for 25-30 hours of students work, 3 ECTS are distributed in the class workload as follows: ● 30 hours: class attendance, 2 unexcused absences are allowed; missing more than 2 classes (even if justified) requires completing an extra assignment ● 25-30 hours: reading for classes, preferably before the lecture ● 25-30 hours: homework assignments and preparations for the exam
Brief course description	The course introduces students to the main approaches to the cognitive systems modeling, provides a broad overview of the modeling methods and their applications, with a focus on dynamical systems perspective. We also explore the need and possibilities of their integration for modeling complex cognitive phenomena.
Full course description	Cognitive systems are characterized by their ability to functionally adapt to their environments, which in turn allows them to react to the changes in their surroundings or initiate actions of their own. Mechanisms of functional adaptation of this kind are found in a wide variety of phenomena spanning multiple scales: biological systems (single cells, cell colonies, organized tissues, systems such as immune system etc.), whole organisms, higher animals and humans with their mental processes, social groups exhibiting cultural adaptation, and populations exhibiting macro-dynamics. Modeling such phenomena requires an interdisciplinary

approach in which different fields of study stimulate each other: psychological and biological discoveries inspire the development of new mathematical models and computational methods, which often find applications outside of the original domain. Developed models help to formulate hypotheses, plan further experiments, verify theories, and augment the overall understanding of cognitive processes. Last but not least, models of the cognitive processes are often inspirations for developing artificial cognitive systems, such as autonomous robots or software agents, which extend human agency in the world.

The aim of this course is to give an overview of the main paradigms, approaches and methods used to model processes of such systemic adaptation. We show how different methods relate to each other and how they can be applied to uncover different aspects of the studied phenomena. We focus on methodological issues and illustrate them with examples of concrete models and concrete research from multiple domains such as motor development, decision making, language acquisition, social coordination, cultural evolution etc.

Learning outcomes

Upon successful completion of the course you will:

- be able to describe the theory and philosophy behind the main paradigms in cognitive modeling, their origins and assumptions (K_W01, K_W02, K_W08)
- know multiple methods used to model cognitive systems, and understand their strengths and weaknesses (K_U01)
- know which experimental paradigms in cognitive science can be a source of data for which types of cognitive modeling (K_W07)
- know the cognitive scientific terminology pertaining to modeling and be able to assess the use of cognitive models in a scientific project and/or paper (K_W08, K_U01)
- be able to communicate concepts related to cognitive modeling within an interdisciplinary team (K_W08, K_U07)
- be able to find information pertinent to main models in cognitive science, understand the fast pace of changes in the field (K_U08, K_K01)
- be sensitive to the use of artificial systems and their relation to human agency within relevant ecosystems (K_K02, K_K07)

Learning activities and teaching methods

Lecture with questions/discussion at the end of each class.

List of topics/classes and bibliography

Obligatory texts: familiarity with the material may be checked via entrance quizzes. Non-obligatory texts are *italicized*.

1. What is a cognitive system? A map for the course [JRL/JZ]:
    a. Von Bertalanffy (1968) „General Systems Theory”: Intro 3-30 (In Polish: Ogólna Teoria Systemów: Wprowadzenie)
    b. Sun, R. (2008). Introduction to Computational Cognitive Modeling. In R. Sun (Ed.). The Cambridge Handbook of

Computational Psychology (pp. 3–19). Cambridge University Press.

2. The main paradigms in cognitive sciences and main paradigms of cognitive modeling. Information processing and dynamical systems in modeling cognition. [JRL]
    a. Rączaszek-Leonardi, J. (2016). Reconciled with complexity in research on cognitive systems. *Avant, Vol. VII*, No. 2, 117-138. [*quiz*]
    b. Favela, L.H., Amon, M.J. (2023). Reframing Cognitive Science as a Complexity Science. Cognitive Science, 47, e13280, p. 1-4 [*quiz*]
    c. *Van Orden, Holden and Turvey (2003). Self-organization of Cognitive Performance. JEP: General, Vol. 132, No. 3, 331–350.*
    d. *Richardson, M., Dale, R., & Marsh, K. (2014). Complex Dynamical Systems in Social and Personality Psychology. In H. Reis & C. Judd (Eds.), Handbook of Research Methods in Social and Personality Psychology. Cambridge: Cambridge Univ. Press*
3. Evolution of artificial intelligence: a case study. [JZ] (discussion)
4. Introduction to Game Theory for Cognitive Scientists [MD]
    a. Jackson, M. O. (2011). A brief introduction to the basics of game theory. Available at SSRN 1968579. [*quiz*]
    b. Jäger, G. (2012). Game theory in semantics and pragmatics. Semantics: An international handbook of natural language meaning, 3, 2487-2516. - Sections 1-3.
    c. *Bonanno, G. Game Theory. An open access textbook with 165 solved exercises, https://arxiv.org/pdf/1512.06808.pdf, - chapters: 1, 2, 9, 13*
5. Nature-inspired computation I: Neural networks as universal models of nonlinear dynamics. Feedforward and recurrent architectures. [JZ]
    a. Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning, MIT Press. (Chapter 1: Introduction)
    b. *Thomas, M., & McClelland, J. (2008). Connectionist Models of Cognition. In R. Sun (Ed.), The Cambridge Handbook of Computational Psychology (Cambridge Handbooks in Psychology, pp. 23-58). Cambridge: Cambridge University Press.*
6. Nature-inspired computation II: Evolutionary and cognitive robotics. [MD]
    a. Doncieux, S., Bredeche, N., Mouret, J. B., & Eiben, A. E. G. (2015). Evolutionary robotics: what, why, and where to. Frontiers in Robotics and AI, 2, 4. [*quiz*]
    b. *http://www.scholarpedia.org/article/Genetic_algorithms*
7. Computational approaches to modeling complexity. Formal languages and automata. [MD]
    a. https://plato.stanford.edu/entries/turing-machine/

   b. *Wells, A. J. (2004). Cognitive science and the turing machine: An ecological perspective. In Alan Turing: Life and Legacy of a Great Thinker (pp. 271-292). Springer, Berlin, Heidelberg.*
8. Logic-based models of cognition. Inference using production rules. Belief–desire–intention model of reasoning. [JZ]
   a. Bringsjord, S. (2008). Declarative/Logic-Based Cognitive Modeling. In R. Sun (Ed.), The Cambridge Handbook of Computational Psychology (Cambridge Handbooks in Psychology, pp. 127-169). Cambridge: Cambridge Univ. Press
9. Statistical models I. The concept of probability and its interpretation. Statistics as a cornerstone of model evaluation. Rational agents and uncertainty. Ecological rationality and bias-variance dilemma. [JZ] (discussion)
   a. Romeijn, J.W. (2014). Philosophy of Statistics, Stanford Encyclopedia of Philosophy: https://plato.stanford.edu/entries/statistics/#StaInd
   b. Gigerenzer, G., & Brighton, H. (2009). Homo Heuristicus: Why Biased Minds Make Better Inferences. *Topics in Cognitive Science, 1*(1), 107–143. [*quiz*]
   c. *Zubek, J., Denkiewicz, M., Dębska, A., Radkowska, A., Komorowska-Mach, J., Litwin, P., … Rączaszek-Leonardi, J. (2016). Performance of language-coordinated collective systems: A study of wine recognition and description. Frontiers in Psychology, 7, 1321.*
10. Statistical models II. Modeling uncertainty with statistical models. Introduction to Bayesian modeling. [MD]
   a. Chater, N., Oaksford, M., Hahn, U. and Heit, E. (2010), Bayesian models of cognition. WIREs Cogn Sci, 1: 811-823. [*quiz*]
   b. Leo Breiman et al. Statistical modeling: The two cultures (with comments and a rejoinder by the author). *Statistical Science, 16* (3):199–231, 2001. - comments not obligatory, but recommended
   c. *Lee, M. D., & Wagenmakers, E.-J. (2014). Bayesian Cognitive Modeling: A Practical Course. Cambridge ; New York: Cambridge University Press.* - Chapter 1; latter chapters cover practical aspects.
11. Statistical models III. Bayesian methods in modeling action and perception. Free Energy Minimization. [WR]
   a. Karl Friston, Christopher Thornton, and Andy Clark. Free-energy minimization and the dark-room problem. Frontiers in Psychology, 3:130, 2012.
   b. *Mathys C, Jean Daunizeau J, Karl J Friston KJ, Klaas Enno Stephan KE. (2011) A Bayesian foundation for individual learning under uncertainty Front. Hum. Neurosci. 5:35*

   c. *Karl J Friston, Jean Daunizeau, and Stefan J Kiebel. Reinforcement learning or active inference? PloS one, 4(7): e6421, 2009.*

12. Describing systems dynamics I. Difference equations, differential equations, phase spaces, attractors, fractals & fractal dimensions. [JZ]
    a. http://www.scholarpedia.org/article/Dynamical_systems [*quiz*]
    b. *http://www.scholarpedia.org/article/Phase_space*
    c. *http://www.scholarpedia.org/article/Attractor*
13. Describing systems dynamics II. Recurrence Quantification Analysis. [JRL]
    a. Leonardi, G. (2012). The Study of Language and Conversation with Recurrence Analysis Methods. *Psychology of Language and Communication, 16,* 2, 165 - 183. https://sciendo.com/article/10.2478/v10057-012-0012-x [*quiz*]
    b. *Fusaroli, R., Konvalinka, I., and Wallot, S. (2014). "Analyzing social interactions: the promises and challenges of using cross recurrence quantification analysis," in Translational Recurrence. Springer Proceedings in Mathematics, eds N. Marwan, M. Riley, A. Giuliani, and C. L. Webber Jr. (London: Springer), 137–155. doi: 10.1007/978-3-319-09531-8_9*
14. Understanding complex relational systems. Structure and dynamics of networks. [ST]
    a. Sections: 2.1, 2.2, 2.3.1, 6.1, 6.4 (circa 25 pages) in: Boccaletti, S., Latora, V., Moreno, Y., Chavez, M., & Hwang, D. U. (2006). Complex networks: Structure and dynamics. *Physics reports*, *424*(4-5), 175-308. [*quiz*]

Assessment methods and criteria	80% Written exam covering the lectures and selected literature 20% Quizzes & Homeworks Additionally, students can improve their grade by actively participating in class discussions during lectures.
Attendance rules	Attendance to the lecture is obligatory, 2 unexcused absences are allowed.
Prerequisites	Basics of cognitive psychology and basic understanding of statistics. Course indicated for 3-5th year students.
Academic honesty	Students must respect the principles of academic integrity. Cheating and plagiarism (including copying work from other students, internet or other sources) are serious violations that are punishable and instructors are required to report all cases to the administration.
Remarks	Since there is no textbook for the course, material covered in lectures and the literature assigned for each lecture, will be the main basis for the exam.